DESCRIPTION

LIQUID-COOLING TYPE COOLING PLATE

This application claims priority under 35 U.S.C.§119 to Japanese Patent Application No. 2004-48451 filed on February 24, 2004, Japanese Patent Application No. 2004-360085 filed on December 13, 2004 and U.S. Provisional Application No. 60/548,909 filed on March 2, 2004, the entire disclosures of which are incorporated herein by reference in their entireties.

Cross Reference to Related Applications

This application is an application filed under 35 U.S.C.§111(a) claiming the benefit pursuant to 35 U.S.C.§119(e)(1) of the filing date of U.S. Provisional Application No. 60/548,909 filed on March 2, 2004, pursuant to 35 U.S.C.§111(b).

Technical Field

The present invention relates to a liquid-cooling type cooling plate, a method for manufacturing the cooling plate, and an electric vehicle equipped with the cooling plate.

In this disclosure including claims, the wording of "electric vehicle" is used to include the meaning of hybrid vehicles. Examples of "vehicles" include automobiles (cars), motorcycles and railroad vehicles.

Background Art

The following description sets forth the inventor's knowledge of related art and problems therein and should not be construed as an admission of knowledge in the prior art.

Electronic components, such as semiconductor devices, multi-chip modules and printed circuit boards, are conventionally used in a state in which the electric components are attached to an air-cooling type cooling plate to release the heat generated during the use. In accordance with increased heat release amount from the electronic components due to the recent improved performance thereof, however, it becomes insufficient for the air-cooling type cooling plate to attain sufficient cooling performance required to such electronic components. To cope with the problem, a liquid (water)-cooling type cooling plate has become used in place of the aforementioned air-cooling type cooling plate.

As such a liquid-cooling type cooling plate, for example, Japanese Unexamined Laid-open Patent Publication No. 2002-170915 (Patent Document 1, see claim 1 and Figs. 1 to 4) discloses that an inner fin is mounted in a casing, and Japanese Unexamined Laid-open Patent Publication No. H10-98144 (Patent Document 2, see claim 1 and Figs. 1 and 2) discloses that a pair of external plates is connected by bolts and nuts with tubes through which cooling liquid passes sandwiched therebetween.

In the former cooling plate, the surface of the cover plate closing the opening of the casing constitutes a cooling surface, and electronic components are attached to the cooling surface to be cooled. On the other hand, in the latter cooling plate, the surface of each external plate constitutes a cooling surface, and electronic components are attached to the cooling surface to be cooled.

In the former cooling plate, although the inner fin is used in order to form cooling liquid passages in the casing, the dimension of the cooling liquid passage that can be formed with this inner fin is, generally, about 1 mm or more in height and about 1 mm or more in width. In order to form a cooling liquid passage smaller than the aforementioned dimension with such inner fin, it is necessary to set the pitch of the inner fin very small, which makes it difficult to manufacture the inner fin.

In the latter cooling plate, the flatness of the cooling surface of the external plate could decrease by the tightening force generated at the time of tightening both the external plates with bolts and nuts. In the state in which the flatness of the cooling surface is decreased, when electronic components are attached to the cooling surface, gaps may be generated between the cooling surface and electronic components, resulting in decreased cooling efficiency. Furthermore, tightening by bolts and nuts may cause deformation of tubes, which may cause deformed or clogged cooling liquid passage of the tube.

The description herein of advantages and disadvantages of various features, embodiments, methods, and apparatus disclosed in other publications is in no way intended to limit the present invention. Indeed, certain features of the invention may be capable of overcoming certain disadvantages, while still retaining some or all of the features, embodiments, methods, and apparatus disclosed therein.

Other objects and advantages of the present invention will be apparent from the following preferred embodiments.

Disclosure of Invention

The preferred embodiments of the present invention have been developed in view of the above-mentioned and/or other problems in the related art. The preferred embodiments of the present invention can significantly improve upon existing methods and/or apparatuses.

The present invention was made in view of the aforementioned problems, and aims to provide a liquid-cooling type cooling plate which is high in flatness of a cooling surface to which members-to-be-cooled, such as electronic components, are attached, high in hardness, and easy in manufacturing. It also aims to provide a method for manufacturing the cooling plate and an electric vehicle equipped with the cooling plate.

To attain the aforementioned objects, the present invention

has the following structure.

[1] A liquid-cooling type cooling plate, comprising:

at least one flat multi-bored tube through which cooling liquid passes;

a substrate having two header forming dented portions arranged apart from each other and a tube accommodating dented portion for accommodating the tube, the tube accommodating dented portion being formed between the header forming dented portions; and

a cover plate disposed on an upper surface of the substrate,

wherein an upper surface of the cover plate and/or a lower surface of the substrate is configured to be attached by a member to be cooled,

wherein the tube is accommodated in the tube accommodating dented portion with the tube communicated with the header forming dented portions,

wherein the tube is disposed between the substrate and the cover plate and an opening of each header forming dented portion is closed by the cover plate in a state in which the cover plate is disposed on the upper surface of the substrate, whereby two header portions are formed, and

wherein the substrate, the tube and the cover plate are integrally jointed such that leakage of the cooling liquid accommodated in the header portions can be prevented.

[2] The liquid-cooling type cooling plate as recited in the aforementioned Item [1], wherein the substrate, the tube and the

cover plate are integrally brazed.

[3] The liquid-cooling type cooling plate as recited in the aforementioned Item [1] or [2], wherein an average equivalent diameter of a cooling liquid passage of the tube is set so as to fall within the range of from 0.05 to 1.7 mm.

[4] The liquid-cooling type cooling plate as recited in the aforementioned Item [1] or [2], further comprising a first connecting member connected to one of the two header portions and a second connecting member connected to the other header portion, wherein the first connecting member and the second connecting member are configured to be connected to a cooling liquid inlet tube and a cooling liquid outlet tube, respectively.

[5] The liquid-cooling type cooling plate as recited in the aforementioned Item [3], further comprising a first connecting member connected to one of the two header portions and a second connecting member connected to the other header portion, wherein the first connecting member and the second connecting member are configured to be connected to a cooling liquid inlet tube and a cooling liquid outlet tube, respectively.

[6] The liquid-cooling type cooling plate as recited in the aforementioned Item [1], wherein the member to be cooled is an electronic component for electric vehicles.

[7] The liquid-cooling type cooling plate as recited in the aforementioned Item [1], wherein the member to be cooled is an electronic component for computers.

[8] A method for manufacturing a liquid-cooling type cooling plate, the method comprising:

a step of preparing at least one flat multi-bored tube through which cooling liquid passes, a substrate having two header forming dented portions arranged apart from each other and a tube accommodating dented portion for accommodating the tube, the tube accommodating dented portion being formed between the header forming dented portions, and a cover plate disposed on an upper surface of the substrate;

a step of accommodating the tube in the tube accommodating dented portion with the tube communicated with the header forming dented portions,

a step of disposing the cover plate on the upper surface of the substrate after the step of accommodating the tube such that the tube is disposed between the substrate and the cover plate and an opening of each header forming dented portion is closed by the cover plate, whereby two header portions are formed, and

a step of integrally jointing the substrate, the tube and the cover plate after the step of disposing the cover plate such that leakage of the cooling liquid accommodated in the header portions can be prevented.

[9] The method for manufacturing a liquid-cooling type

cooling plate as recited in the aforementioned Item [8], wherein in the jointing step, the substrate, the tube and the cover plate are integrally brazed in a brazing furnace.

[10] The method for manufacturing a liquid-cooling type cooling plate as recited in the aforementioned Item [8], further comprising a step of jointing connecting members in which a first connecting member to be connected to a cooling liquid inlet tube is connected to one of the two header portions and a second connecting member to be connected to a cooling liquid outlet tube is connected to the other header portion,

wherein in the jointing step, the substrate, the tube, the cover plate and the connecting members are integrally brazed in a brazing furnace.

[11] The method for manufacturing a liquid-cooling type cooling plate as recited in any one of the aforementioned Items [8] to [10], wherein an average equivalent diameter of a cooling liquid passage of the tube is set so as to fall within the range of from 0.05 to 1.7 mm.

[12] An electric vehicle equipped with a liquid-cooling type cooling plate in which an electronic component as a member to be cooled is attached to an upper surface of a cover plate and/or a lower surface of a substrate of the liquid-cooling type cooling plate,

wherein the liquid-cooling type cooling plate includes:

at least one flat multi-bored tube through which cooling liquid passes;

the substrate having two header forming dented portions arranged apart from each other and a tube accommodating dented portion for accommodating the tube, the tube accommodating dented portion being formed between the header forming dented portions; and

the cover plate disposed on an upper surface of the substrate,

wherein an upper surface of the cover plate and/or a lower surface of the substrate is configured to be attached by a member to be cooled,

wherein the tube is accommodated in the tube accommodating dented portion with the tube communicated with the header forming dented portions,

wherein the tube is disposed between the substrate and the cover plate and an opening of each header forming dented portion is closed by the cover plate in a state in which the cover plate is disposed on the upper surface of the substrate, whereby two header portions are formed, and

wherein the substrate, the tube and the cover plate are integrally jointed such that leakage of the cooling liquid accommodated in the header portions can be prevented.

[13] The electric vehicle as recited in the aforementioned Item [12], wherein the substrate, the tube and the cover plate are integrally brazed.

[14] The electric vehicle as recited in the aforementioned

Item [12] or [13], wherein an average equivalent diameter of a cooling liquid passage of the tube is set so as to fall within the range of from 0.05 to 1.7 mm.

[15] The electric vehicle as recited in the aforementioned Item [12] or [13], wherein the liquid-cooling type cooling plate further includes a first connecting member connected to one of the two header portions and a second connecting member connected to the other header portion, wherein the first connecting member and the second connecting member are configured to be connected to a cooling liquid inlet tube and a cooling liquid outlet tube, respectively.

[16] The electric vehicle as recited in the aforementioned Item [14], wherein the liquid-cooling type cooling plate further includes a first connecting member connected to one of the two header portions and a second connecting member connected to the other header portion, wherein the first connecting member and the second connecting member are configured to be connected to a cooling liquid inlet tube and a cooling liquid outlet tube, respectively.

[17] The electric vehicle as recited in the aforementioned Item [12] or [13], wherein the electric vehicle is further equipped with a radiator, wherein cooling liquid cooled by the radiator is introduced into the cooling plate, and the cooling liquid flowed out of the cooling plate is cooled by the radiator.

[18] The electric vehicle as recited in the aforementioned Item [14], wherein the electric vehicle is further equipped with a radiator, wherein cooling liquid cooled by the radiator is introduced into the cooling plate, and the cooling liquid flowed out of the cooling plate is cooled by the radiator.

Hereinafter, the invention as recited in each Item will be explained.

In the invention as recited in Item [1], since a multi-bored tube is used as a component through which the cooling liquid passes, it is possible to easily manufacture the cooling plate having small cooling liquid passages. Therefore, the cooling plate high in cooling capacity can be manufactured.

Furthermore, in this cooling plate, a member to be cooled is attached to the upper surface of the cover plate and/or the lower surface of the substrate. That is, the upper surface of the cover plate and/or the lower surface of the substrate function as a cooling surface of this cooling plate.

Since the tube is accommodated in the predetermined dented portion of the substrate when the substrate, the tube and the cover plate are jointed, deterioration of the flatness of the cooling surface (i.e., the upper surface of the cover plate and/or the lower surface of the substrate) due to the jointing can be prevented. Accordingly, the flatness of the cooling surface can be kept assuredly.

As a result, a member to be cooled can be attached to the cooling surface in a closely adhered manner, resulting in efficient cooling of the member to be cooled.

Furthermore, since the tube is accommodated in the predetermined dented portion of the substrate, the tubes would not be deformed at the time of jointing the cover plate to the substrate. Therefore, the cooling liquid passages of the tube can be retained in predetermined shape and size.

In addition, since the substrate, the tube and the cover plate are integrally jointed in the state in which the tube is accommodated in the predetermined dented portion and that the cover plate is disposed on the upper surface of the substrate, this cooling plate has high mechanical strength.

In this invention, the member to be cooled by the cooling plate is not limited to a member of a specific type. Examples of members to be cooled includes a semiconductor device, a multichip module, a printed circuit board, an IGBT module, an inverter, a converter, a semiconductor controlling element, a diode, a condenser, a coil, a luminescence component (e.g., lamp), a speaker, a CRT, a hard-disk drive, a DVD drive, and a printer component (e.g., thermal head).

In this invention, the material of the substrate, the cover plate and the tube are not limited to a specific one. Examples of the material include aluminum or its alloy, copper or its alloy,

iron, steel, stainless steel, resin, and ceramics. Among them, especially, it is preferable to use aluminum or its alloy, or copper or its alloy because they are high in thermal conductivity and capable of improving the cooling performance.

Furthermore, in this invention, as a means for jointing the substrate, the tube and the cover plate, brazing can be exemplified. In addition to the above, friction agitation jointing, soldering, thermal-diffusion jointing and adhesives can also be exemplified.

In the invention as recited in the Item [2], since the substrate, the tube and the cover plate are integrally brazed, the thermal conductivity is good, and therefore the cooling performance can be improved.

It is preferable that the tube is an extruded tube. In this case, it is possible to easily manufacture the cooling plate having smaller cooling liquid passages.

The aforementioned extruded tube denotes a tube manufactured by extrusion.

It is also preferable that the tube is a rolled tube. In this case, it is possible to easily manufacture the cooling plate having smaller cooling liquid passages.

The aforementioned rolled tube denotes a tube manufactured

by rolling. Concretely, as disclosed by Japanese Patent No. 2915660 (Japanese Unexamined laid-open Publication No. H5-164484), etc., a rolled tube, which is manufactured by rolling a plate-like material into a thin plate with rollers having a plurality of circular forming dented portions on the peripheral surface to form partitioning ribs for cooling liquid passages formed by protruded rows formed by the forming dented portions of the rolls and then forming the material into a cylindrical tube with a roll forming machine, can be exemplified.

In the invention as recited in the Item [3], since the average equivalent diameter of the cooling liquid passage of the tube is set so as to fall within the range of from 0.05 to 1.7 mm, the cooling capacity of the cooling plate can be improved.

The aforementioned equivalent diameter is a value obtained by dividing the four times of the cross-sectional area of the cooling liquid passage by the wet peripheral length (wetted-circumferential length). That is, de=4A/p, wherein "de" is an equivalent diameter, and "A" is a cross-sectional area of a cooling liquid passage, and "p" is a wet peripheral length.

In the invention as recited in the aforementioned Item [4] and [5], since the cooling plate is equipped with the first connecting member to be connected to a cooling liquid inlet tube and the second connecting member to be connected to a cooling liquid outlet tube, the connecting work for connecting the cooling liquid inlet and

outlet tubes to the cooling plate can be performed easily.

In the invention as recited in the aforementioned Item [6], the cooling plate capable of assuredly cooling electronic components for electric vehicles can be provided. Examples of electronic components for electric vehicles include an IGBT module, an inverter, a converter, a semiconductor controlling element, a diode, a condenser, a coil, and a luminescence component.

In the invention as recited in the aforementioned Item [7], the cooling plate capable of assuredly cooling electronic components for computers can be provided. Examples of electronic components for computers include a CPU, a MPU, a hard-disk drive and a DVD drive.

In the invention as recited in the aforementioned Item [8], since the manufacturing method of the cooling plate includes the step of preparing the tube, the substrate and the cover plate, the step of accommodating the tube, the step of covering the substrate with the cover plate, and the step of jointing the components, the cooling plate according to this invention can be manufactured assuredly and easily.

In the invention as recited in the aforementioned Item [9], since, at the jointing step, the substrate, the tube and the cover plate are integrally brazed in a furnace, the cooling plate can be manufactured more easily.

In the invention as recited in the aforementioned Item [10], according to the manufacture method of the cooling plate, since, at the substrate jointing step, the substrate, the cover plate, the tube and the connecting members are integrally brazed in a furnace, the cooling plate can be manufactured more easily.

In the invention as recited in the aforementioned Item [11], since the average equivalent diameter of the cooling liquid passage of the tube is set so as to fall within the range of from 0.05 to 1.7 mm, the cooling capacity of the cooling plate can be improved.

In the invention as recited in the aforementioned Item [12], since the electric vehicle is equipped with the cooling plate according to this invention and an electronic component as a member to be cooled is attached to the upper surface of the cover plate and/or the lower surface of the substrate of the cooling plate, the electronic component for electric vehicles can be cooled assuredly.

In the invention as recited in the aforementioned Item [13], since the substrate, the tube and the cover plate are integrally brazed, the thermal conductivity is good, and therefore the cooling capacity can be improved.

In the invention as recited in the aforementioned Item [14], since the average equivalent diameter of the cooling liquid passage

of the tube is set so as to fall within the range of from 0.05 to 1.7 mm, the cooling capacity of the cooling plate can be improved.

In the invention as recited in the aforementioned Item [15] and [16], the connecting work for connecting the cooling liquid inlet and outlet tubes to the cooling plate can be performed easily.

In the invention as recited in the aforementioned Item [17] and [18], since the cooling liquid cooled by the radiator mounted in the electric vehicle is introduced into the cooling plate and the cooling liquid flowed out of the cooling plate is cooled by the radiator, the cooling liquid circulates the cooling plate and the radiator. As a result, the electronic component can be cooled more assuredly.

The present invention has the following effects.

According to the invention as recited in the aforementioned Item [1], it is possible to easily manufacture a cooling plate having small cooling liquid passages. Therefore, a cooling plate high in cooling capacity can be manufactured.

Furthermore, the flatness of the cooling surface (i.e., the upper surface of the cover plate and/or the lower surface of the substrate) can be maintained. Therefore, a member to be cooled can be cooled efficiently.

Furthermore, since the tube is accommodated in the dented portion of the substrate, the tube would not be deformed at the time of jointing the cover plate to the substrate. Therefore, the cooling liquid passages of the tube can be retained.

Furthermore, since the substrate, the tube and the cover plate are integrally jointed in the state in which the tube is accommodated in the predetermined dented portion and that the cover plate is disposed on the surface of the substrate, this cooling plate is high in mechanical strength.

According to the invention as recited in the aforementioned Item [2], the cooling capacity of the cooling plate can be improved.

According to the invention as recited in the aforementioned Item [3], the cooling capacity of the cooling plate can be improved.

According to the invention as recited in the aforementioned Item [4] and [5], the jointing work for jointing the cooling liquid inlet and outlet tubes to the cooling plate can be performed easily.

According to the invention as recited in the aforementioned Item [6], the cooling plate capable of assuredly cooling electronic components for electric vehicles can be provided.

According to the invention as recited in the aforementioned Item [7], the cooling plate capable of assuredly cooling electronic

components for computers can be provided.

According to the invention as recited in the aforementioned Item [8], the liquid-cooling type cooling plate according to this invention can be manufactured assuredly and easily.

According to the invention as recited in the aforementioned Item [9], the cooling plate can be manufactured more easily.

According to the invention as recited in the aforementioned Item [10], the cooling plate can be manufactured still more easily.

According to the invention as recited in the aforementioned Item [11], the cooling capacity of the cooling plate can be improved.

According to the invention as recited in the aforementioned Item [12], electronic components for electric vehicles can be cooled assuredly.

According to the invention as recited in the aforementioned Item [13], the cooling capacity of the cooling plate can be improved.

According to the invention as recited in the aforementioned Item [14], the cooling capacity of the cooling plate can be improved.

According to the invention as recited in the aforementioned Item [15] and [16], the jointing work for jointing the cooling liquid

inlet and outlet tubes to the cooling plate can be performed easily.

According to the invention as recited in the aforementioned Item [17] and [18], electronic components for electric vehicles can be cooled more assuredly.

The above and/or other aspects, features and/or advantages of various embodiments will be further appreciated in view of the following description in conjunction with the accompanying figures. Various embodiments can include and/or exclude different aspects, features and/or advantages where applicable. In addition, various embodiments can combine one or more aspect or feature of other embodiments where applicable. The descriptions of aspects, features and/or advantages of particular embodiments should not be construed as limiting other embodiments or the claims.

Brief Description of Drawings

Fig. 1 is a perspective view showing a liquid-cooling type cooling plate according to an embodiment of the present invention.

Fig. 2 is a cross-sectional view taken along the X-X in Fig. 1.

Fig. 3 is an enlarged cross-sectional view of the portion V shown in Fig. 2.

Fig. 4 is a cross-sectional view taken along the line Y-Y shown in Fig. 1.

Fig. 5 is a cross-sectional view taken along the line Z-Z shown in Fig. 1.

Fig. 6 is an enlarged cross-sectional view showing the portion W shown in Fig. 5.

Fig. 7 is an exploded perspective view showing the cooling plate.

Fig. 8 is a flowchart showing the manufacturing process of the cooling plate.

Fig. 9 is a schematic plan view showing an electric motorcar equipped with the cooling plate.

Fig. 10 is a figure (graph) showing the relation between the equivalent diameter of the cooling liquid passage of a tube of the cooling plate and the thermal resistance thereof.

Fig. 11 is a cross-sectional view showing a liquid-cooling type cooling plate according to another embodiment of the present invention, which corresponds to Fig. 2.

Best Mode for Carrying Out the Invention

In the following paragraphs, some preferred embodiments of the invention will be described by way of example and not limitation. It should be understood based on this disclosure that various other modifications can be made by those in the art based on these illustrated embodiments.

Some preferable embodiments of this invention will be explained below.

In Fig. 1, the reference numeral "1" denotes a liquid-cooling type cooling plate according to an embodiment of this invention. This cooling plate 1 is called a cold plate. In this cooling plate 1, pure water, antifreezing liquid, etc. is used as the cooling liquid.

This cooling plate 1 is mounted in an electric motorcar 40 (including a hybrid car) as an electric vehicle as shown in Fig. 9.

In Fig. 1, the reference numeral "2" denotes a member to be cooled by this cooling plate 1. In this embodiment, the member 2 to be cooled is an electronic component for the electric motorcar 40. Examples of such electronic components for electric motorcars include an IGBT module, an inverter, a converter, a semiconductor controlling element, a diode, a condenser, a coil and a light-emitting

component. These electronic components are required to be high in long term reliable operation. Therefore, it is necessary to cool the electronic component assuredly. The aforementioned IGBT module is a power conversion switching element, and the aforementioned inverter is a device for converting direct current of a battery into alternative current for driving a motor.

As shown in Fig. 7, this cooling plate 1 includes a substrate 10, a cover plate 30, a plurality of flat multi-bored tubes 20 (seven tubes in this illustrated embodiment) through which cooling liquid passes, a first connecting member 18a and a second connecting member 18b.

The substrate 10, the cover plate 30, the tubes 20 and the connecting members 18a and 18b are made of metal, more specifically, aluminum or its alloy, respectively.

The upper and side surfaces of the substrate 10 is covered with brazing material. Similarly covered with brazing material are at least the lower surface of the cover plate 30, the peripheral surface of the tube 20 and the peripheral surfaces of the connecting members 18a and 18b. In this invention, the brazing material can be clad on predetermined portions, and the cover plate 30 can be made of a brazing sheet.

As shown in Fig. 7, the upper surface of the substrate 10 is formed into a square shape (a rectangular shape). Furthermore, the

substrate 10 is provided with two header forming dented portions 11a and 11b disposed in parallel at the right and left sides of the central portion on the upper surface of the substrate 10. The substrate 10 is further provided with a tube accommodating dented portion 12 for accommodating the tubes 20 between both the header forming dented portions 11a and 11b on the upper surface of the substrate 10.

Each header forming dented portion 11a and 11b is formed approximately into a quadrangular cross-sectional shape (a rectangular cross-sectional shape). The depth of the tube accommodating dented portion 12 is set to have approximately the same size as the thickness of the tube 20. On the other hand, the depth of each header forming dented portion 11a and 11b is set to have a size larger than the depth of the tube accommodating dented portion 12.

Hereinafter, for the sake of the explanatory purpose, one of the two header forming dented portions will be referred to as a first header forming dented portion 11a, and the other thereof will be referred to as a second header forming dented portion 11b.

The shape and the size of the lower surface of the cover plate 30 are set to the same shape and size of the upper surface of the substrate 10. Therefore, in a state in which the cover plate 30 is disposed on the upper surface of the substrate 10, the openings of both the header forming dented portions 11a and 11b and the opening

of the tube accommodating dented portion 12, which are formed on the upper surface of the substrate 10, is closed by the cover plate 30.

As shown in Fig. 1, on the upper surface of the cover plate 30, a member 2 to be cooled is to be attached. That is, in the cooling plate 1 of this embodiment, the upper surface of the cover plate 30 functions as a cooling surface 1A. The cooling surface 1A (i.e., the upper surface) of the cover plate 30 is formed into a flat shape. Similarly, the lower (rear) surface of the cover plate 30 is formed into a flat shape.

The thickness of the cover plate 30 is set to be smaller rather than the thickness of the substrate 10. In this invention, the thickness of the cover plate 30 is preferably set so as to fall within the range of 0.5 to 5 mm, more preferably 1 to 3 mm.

Each tube 20 has a plurality of cooling liquid passages 21. Each cooling liquid passage 21 is a minute penetrated aperture penetrating the tube 20. The cross-sectional shape of each cooling liquid passage 21 is, for example, square (rectangular), as shown in Fig. 3.

In this invention, the cross-sectional shape of each cooling liquid passage 21 can also be, for example, approximately circular, elliptical, star-shaped or polygonal.

The preferable range of the average equivalent diameter of the cooling liquid passage 21 of this tube 20 will be explained later.

This tube 20 is a tube formed by extrusion, i.e., an extruded tube. However, the tube can be a tube formed by rolling, i.e., a rolled tube. Such extruded tube and rolled tube have been generally used in heat exchangers.

In this embodiment, a plurality of cooling liquid passages 21 of the tube 20 are independent with each other. In this invention, however, some or all of the aforementioned plurality of the cooling liquid passages 21 of the tube 20 can be communicated with each other.

As shown in Fig. 9, the first connecting member 18a is to be connected to a cooling liquid inlet tube 19a in a liquidly sealed manner. On the other hand, the second connecting member 18b is to be connected to a cooling liquid outlet tube 19b in a liquidly sealed manner. Each of the first connecting member 18a and the second connecting member 18b is a short tube with a connecting port at one end thereof, as shown in Fig. 7.

On the longitudinal end surface of the substrate 10, a first connecting member insertion opening 13a communicated with one end portion of the first header forming dented portion 11a, and a second connecting member insertion opening 13b communicated with one end

portion of the second header forming dented portion 11b are formed.

Now, the structure of the cooling plate 1 of this embodiment will be explained below with referring to the manufacturing method.

Fig. 8 is a block diagram showing the steps of manufacturing the cooling plate 1 of this embodiment.

First, the substrate 10, the cover plate 30, a plurality of the flat multi-bored tubes 20, the first connecting member 18a, and the second connecting member 18b are prepared. [Preparation Step 50].

Thereafter, as shown in Fig. 7, a plurality of tubes 20 arranged in line along the widthwise direction are accommodated in the tube accommodating dented portion 12 of the substrate 10 with the tubes communicated with the header forming dented portions 11a and 11b. [Tube accommodation Step 51]

In the step of accommodating the tubes 20, if necessary, brazing material can be disposed between the bottom surface of the tube accommodating dented portion 12 of the substrate 10 and the tubes 20.

Thereafter, the cover plate 30 is disposed on the upper surface of the substrate 10 so as to cover the entire tubes 20. By disposing the cover plate 30 as mentioned above, the tubes 20 are disposed

between the substrate 10 and the cover plate 30, and the openings of the header forming dented portions 11a and 11b of the substrate 10 is closed by the cover plate 30. As a result, as shown in Figs. 5 and 6, two header portions 14a and 14b are formed in the substrate 10. [Cover plate disposing step 52].

In the step of disposing the cover plate 30, brazing material can be disposed between the substrate 10 and the cover plate 30 and/or between the tubes 20 and the cover plate 30.

Hereinafter, for the sake of the explanatory purpose, one of the two header portions will be referred to as a first header portion 14a formed by the first header forming dented portion 11a, and the other thereof will be referred to as a second header portion 14b formed by the second header forming dented portion 11b.

Before the step of disposing the cover plate 30, simultaneously with the step of disposing the cover plate 30, or after the step of disposing the cover plate 30, the first connecting member 18a and the second connecting member 18b are inserted into the corresponding insertion openings 13a and 13b, respectively, so that the first connecting member 18a is connected to the first header forming dented portion 11a (the first header portion 14a) in liquid communication, and the second connecting member 18b is connected to the second header forming dented portion 11b (second header portion 14b) in liquid communication. [Connecting member connecting step 52]

Thereafter, the cooling plate assembly assembled as mentioned above is introduced in a brazing furnace, so that the substrate 10, the tubes 20, the cover plate 30, the first connecting member 18a, the second connecting member 18b are simultaneously brazed with each other. [Brazing step 53]

In this brazing step, the substrate 10 and the cover plate 30 are integrally jointed with each other in a liquidly sealed manner, or in a state in which the leakage of the cooling liquid C accommodated in each header portions 14a and 14b is prevented. Furthermore, the first connecting member 18a and the second connecting member 18b are secured in the corresponding insertion apertures 13a and 13b in a liquidly sealed manner. In Fig. 3, the reference numeral "47" denotes a fillet of the brazing material.

Through the aforementioned steps, the cooling plate 1 of this embodiment shown in Fig. 1 is obtained.

As shown in Fig. 9, the cooling plate 1 of this embodiment is mounted in an electric motorcar 40. In this electric motorcar 40, an existing radiator 41 for cooling cooling liquid is mounted. This radiator 41 is disposed at the front portion of the electric motorcar 40. The reference numeral "44" denotes a fan for the radiator and the reference numeral "45" denotes a wheel.

To the first connecting member 18a of the cooling plate 1,

a cooling liquid inlet tube 19a is connected in a liquidly sealed manner. On the other hand, to the second connecting member 18b of the cooling plate 1, a cooling liquid outlet tube 19b is connected in a liquidly sealed manner. The cooling liquid cooled with the radiator 41 is introduced into the cooling liquid inlet tube 19a. The cooling liquid flowed out of the cooling plate 1 is introduced into the cooling liquid outlet tube 19b. Thereafter, the cooling liquid is returned to the radiator 41.

As shown in Fig. 1, a member 2 to be cooled (i.e., an electronic component for electric motorcars) is mechanically fixed to the cooling surface 1A (i.e., the upper surface of the cover plate 30 of the cooling plate 1) with bolts, etc. via high heat conductive compound, paste, sheet, etc. (not shown).

As shown in Fig. 9, in this electric motorcar 40, the cooling liquid cooled by the radiator 41 is sent to the cooling plate 1 through the cooling liquid inlet tube 19a via the reserve tank (receiver tank) 42 with a pump 43. Thus, as shown in Fig. 4, this cooling liquid C is introduced into the first header portion 14a through the first connecting member 18a of the cooling plate 1. The introduced cooling liquid C diverges in plural paths at the first header portion 14a and passes through the passages 21 of each tube 20. When passing through the tubes 20, the cooling liquid C cools the member 2 to be cooled by taking the heat therefrom. The cooling liquid C flows into the second header portion 14b to be merged therein. Then, the merged cooling liquid C flows out of the

second connecting member 18b. Thereafter, as shown in Fig. 9, the cooling liquid C is introduced into the radiator 41 through the cooling liquid outlet tube 19b and then again returned to the radiator 41 to be cooled therein. Thus, the cooling liquid C circulates through the radiator 41 and the cooling plate 1 in this electric motorcar 40.

In this cooling plate 1 of this embodiment, since multi-bored tubes 20 are used as components through which the cooling liquid passes, it is possible to manufacture a cooling plate 1 having small cooling liquid passages 21. Therefore, a cooling plate 1 high in cooling capacity can be manufactured.

The tube 20 is configured to be accommodated in the predetermined dented portion 12 of the substrate 10 when the cover plate 30 is jointed to the substrate 10. This prevents deterioration of the flatness of the cooling surface 1A (i.e., the surface of the cover plate 30) at the time of the jointing. Therefore, the flatness of the cooling surface 1A can be retained assuredly. Therefore, the member 2 to be cooled can be attached to the cooling surface 1A without causing any gaps therebetween, resulting in efficient cooling of the member 2 to be cooled.

Furthermore, since the tubes 20 are accommodated in the predetermined dented portion 12 of the substrate 10, the tubes 20 would not be deformed at the time of jointing the cover plate 30 to the substrate 10. Therefore, the cooling liquid passages 21 of

each tube 20 can be retained in predetermined shape and size.

In addition, since the substrate 10, the tube 20 and the cover plate 30 are integrally jointed in the state in which the tubes 20 are accommodated in the predetermined dented portion 12 and that the cover plate 30 is disposed on the surface of the substrate 10, this cooling plate 1 is high in mechanical strength.

Furthermore, since the substrate 10, the tubes 20 and the cover plate 30 are integrally brazed, the thermal conductivity is good, which in turn can further increase the cooling capacity of the cooling plate 1.

Furthermore, since the tubes 20 are extruded tubes or rolled tubes, the cooling plate 1 having smaller cooling liquid passages 21 can be manufactured easily.

Furthermore, since the cooling plate 1 is equipped with the first connecting member 18a to be connected to the cooling liquid inlet tube 19a and the second connecting member 18b to be connected to the liquid outlet tube 19b, the connecting work of the cooling liquid inlet tube 19a and outlet tube 19b can be performed easily.

Furthermore, the manufacturing method of the cooling plate 1 of this embodiment includes the preparation step 50 for preparing the substrate 10, the tube 20, the cover plate 30, the first connecting member 18a and the second connecting member 18b, the accommodation

step 51 for accommodating the tube 20, the cover plate disposing step 52 for disposing the cover plate 30, the connecting member connecting step 52 for connecting the connecting members 18a and 18b, and the brazing step 53. Furthermore, in the brazing step 53, the substrate 10, the tubes 20, the cover plate 30 and the connecting members 18a and 18b are integrally brazed in a furnace. Accordingly, the cooling plate 1 can be manufactured very easily.

Furthermore, since the electronic component for electric motorcars 40, which is a member 2 to be cooled, is attached to the cooling surface 1A of this cooling plate 1, the electronic component can be cooled assuredly, which in turn can secure the high reliability of the electric component for a long period of time.

Fig. 10 is a figure (graph) showing the relation between the equivalent diameter of the cooling liquid passage 21 and the thermal resistance when the power of the pump 43 for making the cooling liquid flow into the cooling plate 1 is constant in the cooling plate 1 of this embodiment.

The equivalent diameter "de" is obtained by the following formula (i):

$De=4A/p$…(i)

wherein "A" is a cross-sectional area of the cooling liquid passage 21 of the tube 20, and "p" is a wet circumferential length.

Generally, although the absolute value of the thermal

resistance changes with the size of the cooling plate 1, the change tendency of the thermal resistance with respect to the equivalent diameter does not depend on the size of the cooling plate 1, but becomes the same as that shown in this figure.

As shown in this figure, in the case where the equivalent diameter of the cooling liquid passage 21 of the tube 20 is set so as to fall within the range of from 0.05 to 1.7 mm, the thermal resistance becomes small and, therefore, high refrigeration capacity can be demonstrated. In the case where this equivalent diameter is set so as to fall within the range of from 0.1 to 1.05 mm, the thermal resistance becomes smaller, and therefore higher refrigeration capacity can be demonstrated. Furthermore, in the case where this equivalent diameter is set so as fall within the range of from 0.15 to 0.7 mm, the thermal resistance becomes much smaller, and therefore much higher refrigeration capacity can be demonstrated. Accordingly, the average equivalent diameter is preferably set so as to fall within the range of from 0.05 to 1.7 mm, more preferably 0.1 to 1.05 mm, still more preferably 0.15 to 0.7 mm.

Although an embodiment of the preset invention was explained above, the present invention is not limited to the aforementioned embodiment, and can be changed variously.

For example, in the present invention, as shown in Fig. 11, the cooling plate 1 can be designed such that members 2 and 2 to

be cooled can be attached to both surfaces of the cooling plate 1, i.e., one on the upper surface of the cover plate 30 and the other on the lower surface of the substrate 10. In this case, both the upper surface of the cover plate 30 and the lower surface of the substrate 10 functions as cooling surfaces 1A. Furthermore, in the present invention, the cooling plate 1 can be configured such that a member 2 to be cooled can be attached only to the lower surface of the substrate 10. In this case, only the lower surface of the substrate 10 functions as a cooling surface 1A.

In the present invention, the number of tube 20 can be one or more.

Furthermore, in the present invention, the header portion 14a (14b) can be provided with partitioning members (not shown) for causing the cooling liquid flow in a zigzag manner in the cooling plate 1

In the present invention, the cooling plate 1 can be configured to be mounted in a motorcycle, a railroad vehicle, etc., as vehicles, to cool electronic components for such vehicle.

Furthermore, in the present invention, the cooling plate 1 can be configured to be mounted not in a vehicle but in a computer to cool the computer electronic components. In this case, it is possible to cool such computer electronic components assuredly.

Industrial Applicability

The liquid-cooling type cooling plate and the manufacturing method according to the present invention can be utilized as a liquid-cooling type cooling plate and its manufacture method for cooling various heating elements (members to be cooled), such as electronic components for electric motorcars and electronic components for computers. The electric vehicle according to the present invention can be utilized as an electric vehicle carrying the liquid-cooling type cooling plate capable of cooling electronic components for the electric vehicle assuredly.

While the present invention may be embodied in many different forms, a number of illustrative embodiments are described herein with the understanding that the present disclosure is to be considered as providing examples of the principles of the invention and such examples are not intended to limit the invention to preferred embodiments described herein and/or illustrated herein.

While illustrative embodiments of the invention have been described herein, the present invention is not limited to the various preferred embodiments described herein, but includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed

in the claims and not limited to examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive. For example, in the present disclosure, the term "preferably" is non-exclusive and means "preferably, but not limited to." In this disclosure and during the prosecution of this application, means-plus-function or step-plus-function limitations will only be employed where for a specific claim limitation all of the following conditions are present in that limitation: a) "means for" or "step for" is expressly recited; b) a corresponding function is expressly recited; and c) structure, material or acts that support that structure are not recited. In this disclosure and during the prosecution of this application, the terminology "present invention" or "invention" may be used as a reference to one or more aspect within the present disclosure. The language present invention or invention should not be improperly interpreted as an identification of criticality, should not be improperly interpreted as applying across all aspects or embodiments (i.e., it should be understood that the present invention has a number of aspects and embodiments), and should not be improperly interpreted as limiting the scope of the application or claims. In this disclosure and during the prosecution of this application, the terminology "embodiment" can be used to describe any aspect, feature, process or step, any combination thereof, and/or any portion thereof, etc. In some examples, various embodiments may include overlapping features. In this disclosure and during the prosecution of this case, the following abbreviated terminology may be employed: "e.g." which means "for example;" and "NB" which means "note well."